PAPERS READ.

A CONTRIBUTION TO THE GEOLOGY AND PETROGRAPHY OF BATHURST, NEW SOUTH WALES.

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(Plates xiv.-xviii.)

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i. Introduction.

The material embodied in the following paper, is the result of observations, made at intervals, during the last ten years. A residence of some eight years in Bathurst gave me special facilities to study the geology of the district. During that time I have carefully examined some 180 square miles of country, taking the City of Bathurst as a centre. Although I am conscious the paper deals with nothing that may be regarded by geologists as novel or striking, for all that, it may be acceptable to place on record my observations on a district on which very little has hitherto been written. The present contribution will, I hope, be merely an introduction to the geology of a portion of the country that presents rare facilities for the study of many of the great questions connected with the nature of metamorphism, and the phenomena presented by altered strata in the regions of eruptive rocks.

The hand-specimens which accompany this paper will help to make clear descriptions of rocks of uncertain affinities. The micro-photographs of rock-slices, on Plate xiv., will also help to illustrate the structure of the basalts. This is all the more useful in the present unsettled state of petrological nomenclature. As there is a growing tendency among petrologists to follow Professor Rosenbusch's classification of the eruptive rocks, I have, as far as possible, referred the Bathurst rocks to his system.

There are many interesting questions immediately connected with the geology of Bathurst not touched on in this paper. The contact area, for instance, that forms a fringe of metamorphic rock around the central boss of granite, would demand more knowledge and experience in the refinements of modern petrographic methods than I can lay claim to. In fact I have studiously avoided, or merely pointed out, debatable questions. But, having described what almost all geologists are agreed on, the way is clear in the future to deal with the more obscure, but possibly the more interesting, problems that may be studied in and around Bathurst. In dealing with the microscopic structure of the basalts and granites I have received much kind assistance from our leading petrologist—A. W. Howitt, Esq., F.G.S., now Under Secretary for Mines, Melbourne.

ii. Area dealt with.

I propose to deal with the geology of the country immediately around Bathurst. Every reference contained in this paper deals with localities or sections that are included in a circle having a radius of ten miles, taking Bathurst as a centre. A few interesting features outside these limits will be referred to when presenting points of interest known to me. These may serve as a guide to future students.

The stretch of country forming, for the most part, the well-known Bathurst "plains" is, in reality, part of a plateau, on an average about 2350 feet above sea level. Bathurst Railway Station is 2153 feet above sea level, and the highest point of the Bald Hills is some 630 feet above this datum. The extreme difference in level between any two points in the district referred to may be taken as 740 feet.

iii. Previous Observers.

The first reference I can find to the geology of Bathurst is contained in Captain Wilkes' "Narrative of the United States Exploring Expedition," Vol. II. p. 259.* In this work reference is merely made to the fact that the plains of Bathurst were at no distant date an inland lake.

Mr. Stutchbury, who was appointed Geological Surveyor in 1850, made frequent reference to the Bathurst district in his reports to the Colonial Secretary. The only reference of his to the country immediately around the City of Bathurst that I can find is contained in a report, dated "Belabula Rivulet, Carcoar, County Bathurst, April 12th, 1851."

* Narrative of the United States Exploring Expedition during the years 1838-1842, by Charles Wilkes, Commander; Philadelphia, 1842.

Speaking of the country on the Western Road, between Junction Hill and Bathurst, he says,* "The rounded blocks, which when free upon the surface, appear to be immense boulders, or erratic blocks, are not such, but large glandular or globular masses, often connected by veins, and evidently intruded subsequently; these may be seen in many places in the road-side sections, imbedded in coarse granite, traversed by quartz veins in all directions.

"The foot of the hill is composed of disintegrated granite, forming a loose sand. About one mile east of the river the granite is overlaid by clay slate, 'killas.' Granite, with fragmentary trap-rock, appears to form the whole of the country to Macquarie and Bathurst plains; the plains are alluvium, and, judging from the debris in the water-runs, most probably investing granite.

"Lead mines were reported as occurring at Brucedale, near Peel, about eight miles from Bathurst, a little eastward of north, the residence of Mr. W. Suttor; the road then contains much micaceous sand and quartz pebbles.

"On descending the last hill, about two miles from the house, blocks of decomposing granite are occasionally observed; upon crossing the creek it is found, in place upon a ridge running nearly east and west, associated with mica slate, much disturbed, passing into clay slate; the dip of the clay slate is west north west.

"To the eastward of south, half a mile from Mr. Suttor's house, a mine has been opened, in which the following varieties of ore have been found:—

"Sulphuret of lead, with arsenical pyrites.
"Green phosphate of lead, in veins in the clay slate.
"Arsenio-phosphate of lead, and
"Argentiferous sulphuret of lead.

"The cross lodes make their way west north west through clay slate, the angle of dip being 50°.

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* Geological Survey Papers, laid upon the Council Table by the Colonial Secretary and ordered by the Council to be printed; 2nd December, 1851.

"The mines, as at present exhibited, do not promise to be remunerative; the ore appears to be sporadic rather than in regular lodes.

"On the eastern side of the creek there are numerous fragments of grit stone, containing impressions and casts of Spirifiræ, evidently belonging to the coal measure; these must have been transported some distance."

In a paper by the Rev. W. B. Clarke on the Transmutation of Rocks in Australasia, read to the Philosophical Society of New South Wales in May, 1865, mention is made of metamorphic rocks near Bathurst. Says Mr. Clarke, "One of the most remarkable changes I have ever noticed in the neighbourhood of granite occurs a little south of Bathurst. . . slates are converted into mica schist and griesen, and limestone is changed into saccharoidal marble."*

In 1867, the Rev. W. B. Clarke, M.A., F.R.S., published the first edition of his "Sedimentary Formations." He refers to the "existence of gneissoid strata and of schists, of very ancient aspect, at Cow Flat, near Bathurst."†

In his annual report for the year 1878, Mr. C. S. Wilkinson, F.G.S., Government Geologist, refers as follows to the geology of Bathurst:—"Immediately north of the village of Perth, near Bathurst, are some table-topped hills—the Bald Hills—capped with basalt. The basalt rests on a very siliceous, tertiary pebble conglomerate, which, in turn, rests on granite. . . . I believe that this basalt is an outlier, or remnant, of the basaltic stream which, in pliocene times, flowed down the Campbell's River valley from near Swatchfield. The basalt is, in places, columnar, and on the Bald Hills this columnar structure is splendidly shown, the

* Trans. Phil. Soc. New South Wales, 1862-1865; Sydney, Reading and Wellbank, 1866, p. 267.

† Remarks on the Sedimentary Formations of New South Wales, by Rev. W. B. Clarke, M.A., F.R.S. (fourth edition); Sydney, Thomas Richards, Government Printer, 1878.

five and six-sided columns being of considerable length and well-formed; sometimes they are curved in a remarkable manner."*

In the annual report of the geological surveyor in charge†, for the year 1879 (p. 214), we find Mr. Wilkinson again making a short reference to Bathurst as follows:—"Following the road from Bathurst to Hill End the first eight miles is over granite, then silurian schists to Wyagdon, then granite again for one mile and a half to near Wattle Flat."

The Department of Mines issued a volume in 1882, entitled "Mineral Products of New South Wales." On p. 39 of this work, Mr. Wilkinson says:—"Near Bathurst upper silurian rocks have been considerably metamorphosed, the sandstones passing into quartzites, slates into gneiss and hornblendic schists, and the coralline limestone into crystalline marbles in which nearly every trace of fossils has been obliterated."

Finally, Mr. W. J. Clunies Ross, B.Sc., read a paper, before the Melbourne meeting of the Australian Association, on the Plutonic and Metamorphic Rocks of Bathurst, New South Wales. Up to the date of writing it has not appeared in print, so that I am unable to refer to the paper in a more detailed manner.

iv. General Geology.

Taking a general view of the district round Bathurst, we have presented to us a central mass of granite, forming the floor, and partly the sides, of a great valley. Higher up the sides silurian rocks rest on the granite. On the floor of this valley a great sheet of recent alluvium shingle and clay deposit is spread, and through these latter deposits the Macquarie has eroded its present bed. A chain of basalt-capped hills rises prominently above the granite floor, forming a line generally parallel to the present river.

* Annual Report of the Department of Mines, New South Wales, for the year 1878; Sydney, the Government Printer, 1879.

† Annual Report of the Department of Mines, New South Wales, for the year 1879; Sydney, the Government Printer, 1880.

An aureole of altered rocks separates the granite from the silurian slates, phyllites or limestones. In short, we have a great saucer-like depression, the edges of which are silurian rocks ; below these there is a belt of hornfels, or metamorphic rocks, and, finally, granite with recent superficial deposits fills the floor of the valley.

Through this valley, as stated already, rising abruptly from the general level, there runs a line of basalt, burying an old river-bed of pliocene age. The granite, from its first appearance to the east, to the boundary of the silurian rocks on the Bathurst-Orange Road, measures some thirty miles across. From the contact rocks on the Winburndale Creek, to the junction of the slate and granite, south of Bathurst, the distance is some eighteen miles, that is 540 square miles. But, allowing for a very irregular line of junction and the small patches of basalt, I take the granite area to measure, at a very moderate estimate, about 460 square miles.

In this area the lowest rocks—granites and hornfels—are the more recent, as will be made clear in another section of this paper.

Surface Geology.

This granite country presents a surface of gently undulating hills and ridges with broad valleys. Except in cuttings in creeks, or on the river-banks, the granite hardly ever shows on the surface, and when it does it is so decomposed as to disintegrate readily and rapidly. As is usual with granite, the decay commences in the felspar grains, thus setting free the other constituents—quartz, hornblende, and biotite. The depth to which decomposition extends varies much ; sometimes to a few feet, and sometimes, in cases that came under my notice, to a depth of 70 feet. The "rolling downs" character of the granite country contrasts strongly with the surface appearances of the surrounding slate. The hills in the slate country show the bed rock freely in escarpments and bars parallel to the strike. The vegetation, moreover, assumes a noticeable change on passing from the granite to the slate country. The accompanying photographs show in an admirable way the difference in weathering in granite and in slate country. Fig. 1

shows the channel of the Macquarie in typical granite rocks. A short distance down stream (Fig. 2) the river passes into silurian slates, dipping at a high angle. The same sharp contrast extends through the country, as a whole, and may be studied to advantage in the hills about Cow Flat to the south of Bathurst, and in the Winburndale Creek, some seven miles to the north of the same town. Immediately round Bathurst the granite is overlain by detrital deposits, varying in age from pliocene to the most recent, or now in process of formation. This applies especially to the strip of country, including that on which Bathurst stands, between the chain of the Bald Hills and the Macquarie River. Deep water-courses have cut through these deposits, exposing beds of alluvium from two to fifteen feet in thickness, or decomposed granite in some instances to a depth of thirty feet. That these erosions have been effected rapidly, that is within the past fifty years, can be readily proved. Some of the old settlers recollect a time when many of these creeks were shallow water channels. Roots of, comparatively speaking, young trees may oftentimes be seen stretching from one wall of these gullies to the opposite one, showing that the very beginning of the erosion must have taken place at a time when the trees were fairly grown. It is impossible not to be struck with the resemblance, in miniature, that some of these creeks with their vertical walls bear to the cañons of Colorado. The photographs exhibited, taken about one and a half miles to the south-west, illustrate these features very clearly. The exact locality lies between the racecourse and the slopes of the Bald Hills. The oldest of these detrital deposits are, undoubtedly, those that flank the Bald Hills, and the more recent are those that form terraces to the present river. Further on we shall see that the line of basalt that crowns the ridges of the Bald Hills marks the course of the one-time bed of the Macquarie. From the time it occupied this position, the river has, at various intervals eroded channels over the whole country between the Bald Hills and the opposite slopes of the valley. In this way are accounted for, the beds of shingle, gravel, and detrital matter that conceal the granite. Large deposits of shingle and water-worn material, marking the position of ancient river beds, may be studied at Kelso, near the Railway Gates; near the Church of England grounds; on the slopes to the right of Kelso-Peel Road, about two miles from Kelso; on the gravel-topped hills between All Saints' College and the General Cemetery; near St. Stanislaus College, and generally on the ridges between the Vale Creek and the Macquarie.

V. Table of formations represented around Bathurst.

POST TERTIARY.	Most recent or now in process of forming ...	A. Deposits of loam, clay, sand, gravels and decomposed granites.
UPPER TERTIARY.	Post Pliocene	B. Gravels and shingle beds, at various levels, between the basalt and the present river bed.
	Volcanic...	C. Basalt flow, capping hills.
	Pliocene	D. Clays, sand, gravels, and conglomerates forming "leads" under basalt.
	Lower Pliocene ...	E. Silicified conglomerates older than "leads."
MESOZOIC ROCKS.—Not represented.		
PALÆOZOIC.	Igneous and Metamorphic	F. Granites.
		G. Hornfels rock, gneissic schists, spotted schists, mica schists and marbles.
	Silurian	H. Clay slates, phyllites, limestones.

vi. Minerals of Bathurst.

Before dealing with the formations and the rocks in detail, it may be well to enumerate the minerals and rocks I have found in the district.

Minerals.

1. Calcite.
2. Apatite.
3. Quartz.
4. Garnet.
5. Olivine.
6. Topaz.
7. Prehnite.
8. Felspar.
    a. Orthoclase.
    b. Plagioclase, Oligoclase.
    c. Albite.
9. Augite.
10. Hornblende.
11. Actinolite.
12. Muscovite.
13. Biotite.
14. Kaolin.
15. Sphene.
16. Galena.
17. Green phosphate of lead.
18. Arsenio-phosphate of lead.
19. Limonite.
20. Mispickel.
21. Pyrites (iron).
22. Magnetite.
23. Copper (native).
24. Malachite.
25. Copper pyrites.
26. Grey ore.
27. Azurite.
28. Argentiferous galena.
29. Gold.
30. Diamond.
31. Manganese (black oxide).

Note.—The following are also reported from Glanmire:—Rhodonite (Annual Report Dept. Mines, N.S.W., 1885, p. 141), manganese ores, and baryta (Annual Report Dept. Mines, N.S.W., 1884, p. 161).

1. *Calcite.*—Calcite is found in veins in the limestones on the Cow Flat Road, about four miles south of the village of Perth. It also forms veins in fissures in the granite. This seems an unusual occurrence, and only two instances came under my notice. It was rather plentiful in a joint or fissure, cut through in the large well of the water-works, Bathurst. There is little doubt but that it is a secondary mineral, formed from the decomposition of some lime felspar.

2. *Apatite.*—Apatite occurs as microscopic needle-shaped bodies in the quartz and felspar crystals of granite. It is very conspicuous in some slices.

3. *Quartz.*—Quartz is very abundant in the district, and is found as veins in the slate rocks adjoining the granite, from a few inches up to some feet in thickness. It may be easily studied in the slate hills about Peel, eleven miles north of Bathurst, and over the country five miles south of Perth. There are large quantities of water-worn quartz on the various terraces that the river has left in eroding its way from the level of the Bald Hills to it present bed. It is almost unnecessary to refer to it as a constituent of the granite. In fine, a very pure form of silica is found, as silicified wood, in drifts that have been denuded of a covering of basalt.

4. *Garnet.*—Garnet, the exact species not determined, occurs in the river sand, and when sand or gravel is washed for gold some garnets are always found. It occurs also as inclusions in the felspars of the granite.

5. *Olivine.*—This mineral is only known as a constituent of the basalt; it rarely attains macroscopic dimensions, but under the microscope it is found in crystals, relatively so large as to give the basalt a micro-porphyritic structure; this is well shown in the rock-slices, Plate XIV. In polished slabs of basalt it can be detected as specks, somewhat darker than the matrix, and easily acted on by warm hydrochloric acid. Infusible before the blowpipe; completely soluble in hydrochloric acid; olive-green in colour; colourless by transmitted light.

6. *Topaz.*—Commonly found with the gem sand washed from the alluvial deposits in searching for gold. I have only met with small stones.

7. *Prehnite.*—A pale green to almost colourless and translucent mineral was found, associated with calcite, filling a fissure in partly decomposed granite at the water-works. I am indebted for my specimen to Mr. W. J. Clunies Ross, B.Sc. It answered as follows to the tests applied—*Streak:* colourless, *Hardness:* 6,

Fracture: even but brittle. Heated in the closed tube, gave off a little water. Dissolves completely in hydrochloric acid. Contains silica, alumina and lime; proportions not determined. Before the blow-pipe intumesces to a porous mass. This mineral I take to be prehnite.

8. *Felspar.*—Orthoclase occurs as a leading constituent in the Bathurst granite. Near White Rock, and other places, it occurs in a porphyritic granite as crystals from half an inch to two inches long. Under the microscope it is more cloudy than plagioclase, which sometimes accompanies it. In most old rocks, when examined in thin slices, orthoclase usually appears more or less impure, on account of foreign substances and cleavage planes that exist in it. In this respect Bathurst orthoclase follows the general rule. No analysis of this mineral has been made, so far as I am aware; but from the intense colours, afforded by Szabo's methods, I am inclined to think the percentage of potash is high. Typical orthoclase contains silica 64·6, alumina 18·5, potash 16·9.

Plagioclase.—It is rare to find a thin section of Bathurst granite entirely free from plagioclase, but there is no predominance of this mineral anywhere in the district over the monoclinic felspar, by which the granites might pass locally into quartz diorites. About four years ago I sent some slices to Mr. A. W. Howitt, then of Sale, and he determined that the triclinic felspar of the Bathurst granite was, in all probability, oligoclase. Triclinic felspars, as one should certainly expect, are abundantly developed as microscopic lath-shaped bodies in the basaltic rocks. Any slice of the Bathurst basalt will show this clearly. See Pl. XIV.

Albite.—Mr. Howitt detected this felspar in some micro-slices I submitted to him in 1886. It occurred as minute veins in orthoclase, placed approximately in the direction of the ortho axis.

9. *Augite.*—This monoclinic pyroxene is known only as a microporphyritic constituent of the basalts. Sections, approximately parallel to the clinopinacoid, are readily obtainable. It also occurs as minute grains in the ground mass of the basalts. Its

abundance in this relation can be ascertained by treating a rock-slice with acid so as to separate the soluble olivine and magnetite.

10. *Hornblende.*—Is found as a macroscopic mineral in the granite ; crystals vary in size, the largest I have noticed measuring from one-sixteenth to one-eighth of an inch along the vertical axis.

11. *Actinolite.*—Found to the south of Bathurst, forming veins in quartz. Most of my specimens come from Cow Flat. It formed fibrous, radiated masses of dark green colour, easily fusible before the blow-pipe. After fusion it becomes strongly magnetic. Specific gravity 3·5.

12. *Muscovite.*—Muscovite, or common mica, is found as an accessory mineral in the Bathurst granites. Towards the edges of the granite mass it often entirely replaces the black mica so characteristic of the typical Bathurst granite. Muscovite occurs in considerable quantities in the river sands. When fresh it is usually colourless, when slightly decomposed it appears as a rich yellow, and an opaque golden hue is very common. It also is found in the sands of almost every creek in the district.

13. *Biotite.*—Black, magnesia, iron mica occurs as small, partly formed crystals and scales, disseminated through the granite, but occasionally, particularly near the edges of the granite rocks, large plates can be detected. By transmitted light it sometimes appears of a deep green colour. After long heating it decomposes in sulphuric acid. Fusible without much difficulty. Plates, corresponding to basal sections, are easily picked out in decomposing granites. The dark colour of the granite is due to the exceedingly large proportion it contains of biotite and hornblende.

14. *Kaolin.*—Kaolin, of various degrees of purity, can be found both as decomposed granite *in situ*, and in small beds of transported material. A pure white kaolin was found on the Bald Hills, a little to the right of the line of section A B marked on the map. When washed free from particles of quartz it formed a tolerably pure kaolin, but the percentage of iron was too high for a marketable article.

15. *Sphene.*—The sands, resulting from the decomposition of the granites, are full of magnetic ironstone and titaniferous iron. This material is so plentiful that after floods it will be found deposited as black sand in the creeks to the south of Bathurst and about Kelso. Mr. A. W. Howitt first drew my attention to it in the micro rock-slices. I have since detected wedge-shaped crystals, of a deep brown colour showing dark borders with transmitted light, in slices of granite from near Mt. Stewart. The titaniferous ironsand may be collected in large quantities by passing a magnet through the dry sand in any of the creeks within the granite area. In this sand I have frequently detected titanium by fusing the mineral with bisulphate of potash until decomposed. The fused mass is then warmed in water in just sufficient quantity to dissolve the soluble material. A few drops of nitric acid are added to the filtrate, and the latter diluted with six or seven times its bulk of water and boiled. Titanic acid separates as a white powder. The powder can be further tested before the blow-pipe in a bead of microcosmic salt.

16. *Galena.*—Is known to occur in veins and lodes in connection with quartz reefs. So far as observed, it is unknown in granite rocks, but is found at, or near, the junction of the slate and granite, both to the north and south of the granite formation. A typical occurrence of this mineral may be studied near the residence of Mr. Suttor at Mt. Grosvenor, Peel. As has been found in other parts of the world, the galena here contains variable amounts of silver. It is not found in such large quantities as to make it profitable as a lead ore. The silver assays are always low, the highest not exceeding 20 oz. per ton of ore.

17. *Phosphate of Lead.*—Occurs sparingly as an incrustation on decomposed galena ore on the Grosvenor Estate, near Peel. I have never detected the arsenical variety of this mineral referred to by Mr. Stutchbury, *ante* p. 176.

19. *Limonite.*—Limonite is found as veins filling cracks or joints in the granite. It is clearly in these instances a secondary

product. It is met with in the excavations at the water-works, and also in a tunnel driven to test the wash in the Bald Hills. Thin layers of this mineral may sometimes be noticed in dried-up water-holes, near the decomposed basalts in the Bald Hills. Clayey ironstones are also found as a cementing material, binding quartz pebbles together, forming post-pliocene river drifts. Peculiar pea-shaped concretions of ironstone are often met with in deposits formed from decomposing basalts.

20. *Mispickel.*—Arsenio-pyrites or mispickel is tolerably abundant in the schistose and slate country along the southern granitic boundary. It occurs both massive and crystallized. This mineral was found in a well, associated with iron pyrites, on Mr. Butler's selection near Green Swamp, on the Kelso-Rockley Road.

21. *Iron pyrites.*—Is very plentiful in the slate country about Bathurst. A very notable occurrence was discovered in a shaft put down by Mr. J. Wilde on Butler's farm, to the south of Perth. The crystals were mostly cubes, and formed the greater part of the rock. Microscopic crystals of pyrites are very common in some of the slates about Cow Flat. I have also noticed yellow iron pyrites in micro-slices of granite from a railway cutting beyond George's Plains; also in slices of the same rock from the base of Mount Pleasant. It can easily be recognised in microscopic sections by reflected light, the bright yellow of the pyrites being clearly seen.

22. *Magnetite.*—This is only known as a microscopic constituent of basalt. It will be referred to, in detail, in dealing with the microscopic structure of the basalts.

23-28. *Copper Minerals.*—It has been already remarked that the metalliferous minerals are confined to the zone of contact rocks. It is in these rocks that native copper, malachite, copper pyrites, grey ore, and azurite have been discovered. I have found native copper in hornfels rock at Duramana, on Kelly's farm. Malachite occurs sparingly at Cow Flat, south of Bathurst. In the specimens I examined it seemed to result from some alteration of azurite or blue carbonate of copper. In keeping with this fact

I have often noticed fibrous green malachite as pseudomorphs after azurite at the Cobar copper mines. Grey copper ore is recorded, on good authority, as occurring in the Cow Flat copper mines. These mines are now closed.

29. *Gold.*—Gold is found in the drifts of the Macquarie, and, more or less abundantly in the shingle beds forming river terraces back to the pliocene "leads." The fact that gold is found in water courses cutting through decomposed granite rocks, such as in those creeks on the common near Bathurst, is thought by some to prove that the gold has been shed from a granitic matrix. While admitting that, in some instances, gold may be derived from a granitic rock,* yet, in our case, it is unnecessary to fall back on any such supposition. I venture to account for the presence of the alluvial gold in this way. The Bald Hills are some 600 feet above the Bathurst Plains. On their summits there rests a layer of basalts covering pliocene drift. This drift has been proved by tunnelling to carry gold. At some points the basalt and underlying drift have been entirely removed by denudations, while along their whole length the margins of the drift have been eroded. The detrital matter, with its auriferous deposit thus obtained, has been spread out between the hills and the river, during all that period that the river has been cutting its way from its old position to its present level. The gold now obtainable in the granite creeks is, in fact, a re-distributed pliocene lead. The character of the gold confirms this theory. It is not possible to distinguish the gold washed from the creeks from some flakes found in the highest drifts. In the creeks referred to the precious metal was never found in quantities sufficient to pay for its recovery.

30. *Diamonds.*—Although I have not seen a diamond from any of the drifts round Bathurst, it may be well to refer to the fact

* For an interesting article on gold in granite, see Clarke's "Southern Gold-fields: Researches in the Southern Gold-fields of New South Wales, by the Rev. W. B. Clarke, M.A., F.G.S.;" Sydney, Reading & Wellbank, 1860.

that the Rev. W. B. Clarke records four diamonds as coming from the bed of the Macquarie, near Suttor's Bar. None have been discovered of late years.

vii. Rocks of Bathurst.

In enumerating the rocks of Bathurst, I think it well to define the terms used in describing the igneous rocks. It makes little matter what system of nomenclature one follows, provided always that the terms are clearly understood. Throughout this paper the rock names will be made use of in the sense here indicated.

ROCKS OF BATHURST.

Igneous Division.

A. *Plutonic Acidic Rocks.*

1. Amphibole granite.
2. Granulite.
3. Aplite.
4. Graphic granite.
5. Greisen.
6. Porphyritic granite.
7. Felsite.

B. *Volcanic Basic Rocks.*

Basalt.

Sedimentary Rocks.

A. *Argillaceous.*

1. Clays.
2. Slate.

B. *Arenaceous.*

1. Sands.
2. Sandstone.
3. Conglomerate.

C. *Calcareous.*

Limestone.

Altered Rocks.

1. Hornfels.
2. Schists.
3. Nodular schists.

vii. Igneous Division.

A. *Plutonic Acidic Rocks.*

1. *Amphibole granite.*—A crystalline, granular rock, composed of quartz + orthoclase + plagioclase + hornblende.* This corresponds to the granulite à amphibole of Fouque and Lévy. These authors, in the splendid work just referred to, define granulite as consisting of black mica, oligoclase, orthoclase, quartz and hornblende. Granulite à amphibole merely differs from this rock in the total or partial substitution of hornblende for black mica.†

2. *Granitite.*—A crystalline, granular rock, consisting of quartz + orthoclase + plagioclase + magnesian mica. This agrees with granitite of Fouque and Lévy.

3. *Aplite.*—A granular compound of potash felspar (orthoclase or microcline) and quartz, with muscovite mica as an accessory.

4. *Graphic granite.*—This variety of aplite, in which the quartz laminæ form figures bearing a fancied resemblance to Hebrew letters, is sometimes found as water-worn fragments about Poor Man's Hollow and at Perth.

5. *Greisen.*—Thin veins of a rock, composed of quartz and mica, may be found near the boundaries of the granite and slate country.

6. *Porphyritic granite.*—In very many parts of the district the felspar crystals of the granite are so large and well-developed, being frequently two and three inches in length, as to entitle the rock to be called porphyritic granite.

7. *Felsite.*—An intimate, granular-crystalline admixture of orthoclase and quartz. Common in the drifts.

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* Rosenbusch, Mikroskopische Physiographie der Massigen Gesteine, p. 29; Zweite Auflage.

† Minéralogie Micro-graphique Roches Eruptives Françaises, pp. 156, 160.

B. *Volcanic Basic Rocks.*

Basalt.—An intimate dark blue or black compound of augite, labradorite and olivine, with some glassy matter. Magnetite and ilmenite are generally present as well. The Bathurst basalt is micro-porphyritic in structure, and, according to Möhl's classification, our rock is a plagioclase basalt. Boricky would call it a felspar-basalt. Rosenbusch makes basalt include all neo-volcanic rocks of basic composition, which essentially contain plagioclase and augite. Olivine, this author does not consider as an essential constituent. As regards structure, this basalt falls under Division 4 in Rosenbusch's classification, and is, therefore, termed hypo-crystalline porphyritic.*

VII. SEDIMENTARY ROCKS.

Argillaceous Rocks.

1. *Clays.*—Composed of hydrous silicate of alumina. The Bathurst clays contain mixtures of sand and iron oxides in various proportions.

2. *Slate.*—Indurated clay, sometimes fissile in planes forming an angle with the bedding, but more often fissile in the direction of the bedding.

Arenaceous Group.

1. *Sand.*—Chemical composition, silica. Mineral components, quartz or flint. Beds of sand are common in many of the more recent formations.

2. *Sandstone.*—The shingle of the drifts consists of siliceous sandstones to a very great extent; pure quartz and felspar pebbles, however, predominate.

3 *Conglomerates.*—This rock consists of rounded pebbles of quartz, sandstone, slate and jasperoid rock, cemented either by siliceous or ferruginous matter. As stated on p. 181, we have two conglomerates, similar in composition but different in age, near Bathurst.

* Rosenbusch, Mikroskopische Physiographie der Massigen Gesteine, p. 728; Zweite Auflage.

Calcareous Rocks.

Limestones.—Chemical composition, carbonate of lime. Some of the crystalline limestones, of a clear white colour, from Cow Flat, are good examples of this rock. At the limekilns, some 18 miles north of Bathurst, there are very considerable beds of limestone. Some are white, but, in most instances, they are blue or grey, from the fact that the last remnants of organic life have not been destroyed.

Altered Rocks.

1. *Hornfels.*—A black or bluish-black rock, close-grained and heavy, with blebs of a milk-blue quartz. In hand specimens this rock might be taken for a fine-grained gneiss or an altered schist. Study of the rock, *in situ*, shows it in every variety, from massive and holo-crystalline to schistose.

2. *Nodular Schist* (Knotenschiefer).—Schists in which small, rounded concretions are present, and which stand out like knots on the planes of foliation. Splendid examples of this rock may be found in a creek by the roadside on the Bathurst-Peel Road. The exact locality is at a point where a small bridge or culvert on the main road crosses a tributary of the Winburndale Creek, near the foot of a steep hill, about 7 miles from Bathurst.

3. *Schistose Rocks.*—The schistose rocks about Bathurst might be described as clay-slates in which layers of mica have been developed and exhibiting distinct foliation. A typical mica schist is an aggregate of quartz and mica only. Hand specimens can be found about Bathurst that cannot readily be distinguished from typical mica schists. But, as a rule, the rocks that I have noticed might be described as felspathic, mica schists, in fact a transition rock, or a variety between the normal type and a gneissic schist. They are abundantly developed about Cow Flat and in the country round the upper Winburndale Rivulet to the north-west of Bathurst.

VIII. Sedimentary Formations.

Upper Silurian.—The slates, gneissic schists, and limestones near Bathurst, have been regarded by all our geologists as of upper silurian age.* The lithological characters of the rocks suggest, almost at first sight, that the slates and limestones are similar in age to well known silurian formations. Very few fossils have been discovered, and all those that have been described point to the same conclusion. De Koninck mentions *Stromatopora striatella*† from the Limekilns 16 miles north of Bathurst. Recently I have collected specimens of the same fossil from the same place. De Koninck also mentions *Favosites fibrosa* from this locality.‡ A short time ago I noticed well preserved examples of the silurian coral, *Phillipsastræa*, near the Benglen Caves Limekilns. Mr. Etheridge, jun., palæontologist to the Australian Museum, to whom I submitted my specimens, informed me that the Phillipsastraea is a new species.§ The fossil evidence stands thus :—

	COLLECTED BY.	IDENTIFIED BY.
Petraia sp.	Suttor. ...	Mines Department.‖
Stromatopora striatella ...	Clarke. Curran. ...	De Koninck.
Favosites fibrosa	Clarke. Curran. ...	De Koninck.
Phillipsastræa sp. ...	Curran. ...	Etheridge, jun.

* Wilkinson, Notes on the Geology of N. S. Wales, p. 39 of Mineral Products of N. S. Wales; Sydney, Government Printer, 1882.

† Recherches sur les Fossiles Paléozoïques de La Nouvelle-Galles du Sud, p. 10.

‡ Fossiles Paléozoïques, p. 22.

§ Mr. Etheridge considers the *Phillipsastræa* a new species. He proposes to describe it at an early date as *P. Currani.* Regarding this coral, he writes, under date 12th February, 1891 :—" *Phillipsastræa.*—This is a very interesting coral and does not appear to be identical with any of the European or American species, so far as the works of reference at my disposal will enable me to judge. *P. Currani* is peculiar in the absence of all trace of a columellarian tubercle, and the central area or calici being entirely tabulate-vesicular, on to which the septa do not pass. De Koninck records *P. Verneuilii,* Ed. & H., as a New South Wales species, but speaks, in his description, of the corallum as composed of superimposed layers, and possessing a thin columella. Neither of these features are present in your specimen."

‖ Annual Report of the Department of Mines, New South Wales, for the year 1881, Appendix H. p. 148; Sydney, Government Printer, 1882.

These are silurian in type. There can be no question that the fossiliferous limestones are interbedded with the phyllites and slates; so the whole formation may be unhesitatingly accepted as silurian in age. There is still additional evidence pointing in the same direction. Resting unconformably on the slates are to be found in places a series of sandstones and grits containing the well known brachiopods *Spirifer disjunctus* and *Rhynchonella pleurodon.* These Devonian rocks are in turn overlaid by carboniferous beds. These successions can be studied well by examining the country to the east of the Bathurst-Limekilns Road, on the upper reaches of the Winburndale, and generally, from the spurs of the Winburndale Mountains, in the same neighbourhood, across to the Limekilns. To sum up, we have evidence from the fossils enumerated, as well as stratigraphical and lithological proofs, of the position of the slate formations in the geological series.

When one approaches Bathurst, from any side, it will be noticed that as the granite region is approached the slates show signs of disturbance. They become more fissile in character, and faults are frequently developed. Contorted strata, principally slate, are to be seen in every creek or favourable cutting. Good examples of this occur about Peel, and an exceptionally good contorted section is exposed in a road cutting on the right of George's Plains and Cow Flat Road. Travelling still towards the granite, glistening plates of mica become apparent on splitting the rock, showing a new phase of crystallization. Further on, the mica becomes more plentiful, so much so as to be recognisable as alternating layers along which the rock easily cleaves. While still nearer the granite the now schistose rock exhibits a peculiar puckered and wavy surface with a satiny sheen. Then dark spots make their appearance, and knots, ovoid and round, stand out on the weathered planes. These spots vary in size from a pin's head to a pea. In this we have an excellent example of the interesting metamorphic slate known as Knotenschiefer. Finally, a mass of rock is met with of a dark blue colour, with no traces of schistosity in any direction, forming a typical hornfels. This interesting succession of zones of contact metamorphism can be followed in a line due north from Mr. Coombe's residence, Glanmire. Spotted schists and hornfels can be followed by travelling up the creek (a tributary of the Winburndale) from the culvert referred to on p. 192. The hornfels will be found exposed between the head of the creek and the road. Hornfels rock, in many interesting varieties, can be collected too at Duramana, where it is used for road purposes. Good outcrops of the same rock are easily accessible in a road cutting on the Orange Road, near the "Rocks," as well as on the Rockley Road, south of Perth, and on the Blayney Road, near the granite boundary.

The aureole of metamorphic rock around the granite may be divided into three zones, but, from the very nature of the case, it is evident that no hard and fast line can be drawn between these belts. The zones may be distinguished as—

1. Zone of micaceous clay slate.
2. Zone of knotted slate, often mica slate (Knotenglimmerschiefer).
3. Zone of hornfels rock.

It will of course be understood that these zones of rock do not follow each other in due succession at every point. That this should be so would suppose denudation to have excavated the river valley equally on all sides—a manifest impossibility. As a matter of fact knotted and altered slates may be found at times nearer the central granite mass than hornfels rock. But this difficulty is easily explained by assuming an underlying mass of granite not yet exposed, or by noticing that sometimes the granite dips away under the slate rock at a low angle and further on comes once more to the surface.

Relative Age of the Sedimentary Rocks.—Silurian slate is the oldest rock around Bathurst. At first sight this may seem rather puzzling. The position and structure of these slates show them to be sedimentary in origin. But we have abundant proof that they were laid down, consolidated, and crushed into great folds long before the granite was erupted. Of course we might suppose the granite to be the result of extreme metamorphism, as possibly some granites are, but in studying the geology of Bathurst one soon abandons all hope of maintaining such an origin for the granitic mass as a whole. This will be dealt with further on.

Wherever I have studied good junctions I always noticed that the slates are cut off suddenly by the granite, and in no instance have I ever seen a slate rock resting on a granitic floor in a way that would suggest it was *originally laid down there*. Indeed, no idea can now be formed of what may have been the character of the old sea-bed on which the sediments were first deposited. No trace or vestige of it remains. The granite behaves in every respect as a rock that was erupted into overlying slates, and is, therefore, the newer. Slate, then, we take to be the most ancient formation. Next in age come the granites. The overlying Devonian rocks are, of course, more recent than either.

From the character of the material forming the great bulk of the slates, we can surmise that the rocks were formed on a deep sea-bottom. The margins of any sea-bed would naturally be made up of coarser material. Rocks, corresponding to these deposits, are abundantly represented. The lines of limestone had an origin not unlike the coral reefs of our own day. The proximity of limestone to conglomerates points to the presence of a shallow sea or sea-beach. The old silurian ocean had its lines of coast, and there must have been a continent at no great distance off, the wearing down of which supplied the material to form the rocks we are discussing. In what direction did this continent lie? What was the nature of its rocks? Has it disappeared to its very foundations? These are questions, full of interest as they are to the geologist, to which no satisfactory replies can be given.

The only formations resting on the granites and slates are the drifts. These are all of tertiary and post-tertiary age. Between these two widely separated formations there exists an immense interval, regarding which the rocks of Bathurst contribute nothing to our knowledge. It is difficult to think that no other rocks, Devonian, Carboniferous, or Jurassic, ever existed above where

Bathurst now stands. Evidence is accumulating to show that the Devonian rocks, found both to the east and west of Bathurst, once formed a great anticlinal fold over the granite. This, probably, formed an island in Carboniferous and Jurassic seas. But all direct proof is missing and practically nothing is known of the physical surroundings of this district from Devonian to Jurassic times. The most tenable opinion is that we had dry land hereabouts when the Carboniferous formations to the north and west were being deposited. This means that rivers from Bathurst mountains flowed into Carboniferous and probably Mesozoic seas, and that our hills were old when many parts of Europe and Asia were still under water.

The drifts referred to are all alluvial, marine deposits being quite unknown. Every drift about Bathurst owes its origin to the present river. The oldest deposit is some 540 feet above the present bed, so that the amount of eroded matter is very considerable. By joining the basalt hills marked F, A, H, K, on the accompanying map (Pl. XVIII.), the bed of the old pliocene river may be approximately traced. These basalt hills were, there is no doubt, once continuous, and the gaps now present are the result of subaërial denudation. The history of the changes, since the days when the Macquarie flowed through this channel nearly 600 feet above its present level, is shortly this. The river was the main drainage line of the country, therefore, the lowest depression within the water-shed. Active volcanoes were pouring out floods of lava about Swatchfield and Orange. One of these streams of liquid rock flowed down and filled up the valley of the Macquarie. The river waters were thus displaced and forced to erode for themselves a new channel. The granite proved more yielding than the compact basalt, so that while the basalt remains the granite has been subjected to every agent of denudation. In effecting this we can with much reason suppose the river to have been a far greater stream that it is now. Volcanic eruptions are always attended with atmospheric disturbance and heavy rains; moreover, the rainfall was undoubtedly greater. Then the rock was, in all probability, suffering from *la maladie du granite* so noticeable now.*

A glance at section i, Pl. XVI. will show some of the various positions of the river from its oldest bed to its present course. The remnants of old channels on the slopes between the river and the Bald Hills vary in age. The oldest drift we know to be Pliocene. The newest is now forming, and the most we can do is to point out that the drifts cover intervals from the Pliocene to this day.

IX. IGNEOUS ROCKS.

Granite—In the field.—There is no lack of outcrops of granite, even within the limits of the sketch map appended. Wherever the granites show on the surface they are decomposed. This is so constant a character that it may be taken for granted that the whole surface of the granite is undergoing rapid decomposition, as stated in a former part of this paper. In sinking wells, ten and twenty feet of decomposed rock are frequently met with. All along the river valley wherever the rock crops out it is invariably decomposed. Indeed, Bathurst affords a good instance of the sickening of granite referred to by Dolomieu. Even when the minerals of the rock hold firmly together, their slices, cut from surface specimens, show cloudy felspars and incipient kaolinization. For microscopical purposes the best locality to procure chips for micro-slices is at the waterworks, where a deep shaft has been put down, and among the broken boulders on the northern slopes of Mt. Pleasant.

Granite is exposed up the river to O'Connell's Plains, and along the railway line to Locksley. Between Locksley and Brewongle some interesting junctions may be noted, one in particular at a bridge crossing the line between the two stations. Following the

* The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighbourhood of Clermont. This decay was called by Dolomieu "la maladie du granite." The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures. Lyell's Principles of Geology, 11th edition, Vol. I. p. 409.

line west, good junctions of the Silurian rock and granite can be seen a little to the Bathurst side of Newbridge Station. Decomposed granite is exposed in a cutting on the river bank at the foot of George Street, near the railway gates, Kelso, near the rifle butts, at Rankin's Bridge, in the railway cuttings between Bathurst and Brewongle, and in almost any of the creeks on the slopes of the Bald Hills. Following the river down, junctions of slate and granite rocks will be found in the neighbourhood of the "Forge," some sixteen miles from Bathurst. The change from the granite to the slate country is very marked in this vicinity. The granite rocks are worn into smooth boulders, reminding one of the *roches moutonnées* produced by ice action, while the slate shows jutting points and pinnacles that conform more or less to the strike of the slate. Boulders of a hard, undecomposed granite are to be found on the railway line beyond Wimbledon. Porphyritic granite is common, but limited in quantity, in each locality. There are some good specimens near the river crossing on the road to White Rock.

A rather noticeable feature in the Bathurst granite is the inclusions that are by no means rare. These vary from a few inches to many yards in length. The prevailing tint of the granite is a light bluish-grey. The inclusions are always dark coloured. When examined minutely they are found to consist of the same material as the body of the granite in a finer state of division. These inclusions contain a considerable amount of titanic or magnetic iron. When the rock is powdered a magnet will separate it readily. If the Bathurst granite is of metamorphic origin, then the inclusions may represent fragments of the original parent rock that have withstood metamorphism. On the other hand, they might represent fragments of slate caught up by the molten granite. After studying a great many of these inclusions, I find it hard to believe that they are the result of any chemical or selective influences in the cooling mass. I rather incline to the view that they are mechanical. Some of the inclusions consist entirely of black mica, felspar and quartz. There is no sharp line separating the one from the other.

In weathering, the granite gives rise to a rather poor and barren soil. Fortunately, soils resulting from either granites or sandstones are seldom found alone. Everywhere there is spread about a certain amount of alluvium from the old river beds. And over large tracts traces of a rich soil, resulting from the decomposition of basalts, can be detected.

Origin of the Granite.—There is a growing belief in the metamorphic origin of many granites. The Bathurst granite, being limited in extent and easily accessible to its boundaries, presented special facilities to study its origin. It is now a common position for geologists to hold that, although in many and perhaps most instances, granite is an intrusive rock of plutonic origin, yet granites do occur which are the result of extreme metamorphism. Examples are eagerly sought for to show that granite can be produced by the metamorphism of sedimentary materials *in situ.*

At the very outset I may state that although I am tolerably familiar with the line of junction between the slates and granites, I have never met with one instance of a gradual change by which granite could be said to melt away on all sides into the surrounding strata, or in which an undoubted granite shades off, by gradations, into a rock of clastic origin. In studying the origin of the granite, the boundaries and junction lines will naturally afford interesting material. Are these boundaries marked by a hard and fast line? Does the granite mass behave like an eruptive rock? Does it alter the rocks it touches? Does it thrust dykes and veins into the rocks around, or do the many square miles of granite melt away, by insensible gradations, into slates and phyllites?

Wherever I have observed contacts, the line of junction has been hard and fast. The granite does thrust out veins into the slates near it, and, without doubt, it alters clay slates to hornfels. The granite is, therefore, in a sense intrusive, but this does not exclude the view that it may have been, for all that, derived from pre-existing sediments. I will now describe a few instances that will maintain my position as to the intrusive nature of the granite, and then consider the probabilities of its being derived from pre-existing sedimentaries.

A junction of granites and Silurian rock can be well seen near the bridge over the Winburndale Creek, on the Bathurst-Peel Road, a few hundred yards up stream. Two rocks are noticeable, one of flesh-coloured granite, which is very marked in its contrast with the other, a massive, compact, bluish rock—a hornfels or altered slate. The granite is mainly binary with strings and nests of translucent quartz. There are occasional flakes of black mica, and layers of white mica are sometimes developed along the joints. The flesh-coloured porphyritic granite sends veins of varying thickness into the hornfels. One vein, not above an inch in thickness, is shot in a right line into the altered slate for fully 20 yards ; see Pl. xv. fig. 5.

In the same locality I noticed a granitic vein springing from the main mass of granite and entering the hornfels as a dyke about a foot thick. A short distance away it is narrowed down to five inches, at the same time bending round to form a right angle with the first direction and then continuing in a right line in its new course. Smaller veins connect the two arms at the angle. A diagram of this interesting intrusion will be found on Pl. xv. fig. 6.

A little further along the same road, in the direction of Bathurst, a tributary of the Winburndale is crossed. It is dry at most seasons of the year. By following up this creek, a variety of rocks will be met with, indicating that the junction of the slate and granite is not far off. Near the culvert, in fact under it, splendid samples of "spotted slate" can be found with a general strike to the north-west.

I will narrate, in the order they are met with, some of the varieties of rocks that may be studied here, following the creek up from the road.

1. Some three hundred yards from the culvert there is a vein of felspathic rock, containing blebs of translucent quartz, silvery mica, and quartz veins. This is some three feet in thickness, and contains inclusions of a schistose hornfels.

2. Slate, dipping north-east at a high angle.

3. A granitic dyke, with inclusions of a schistose hornfels. The general direction conforms to that of the slate. It consists of felspar, quartz and white mica. Besides the mica distributed through the rock, there occur nests of the same mineral, oftentimes with the mica contorted and broken.

4. Spotted slate, with occasional thin veins of quartz.

5. A dyke of granite, with large felspars and white mica. There are layers of white mica on every joint.

6. Slate.

7. Coarse granite, with parallel jointings.

8. Spotted slate.

9. Granite vein, some six yards wide, in places almost as fine-grained as a felsite. The rock is rendered porphyritic in places by nests of silvery mica and felspar. There are also thin veins of quartz.

10. A thick belt of spotted slate, nearly two hundred yards wide, with occasional thin veins of quartz.

11. A vein of granite, with black mica.

So far, although we are approaching the main granitic mass, neither black mica nor hornblende has yet been developed.

12. Boulders of porphyritic granite, with dark fine-grained inclusions.

13. Beyond these last named rocks there are few exposures of the bed rock, but some hundred yards further on the typical Bathurst granite is met with, containing both hornblende and black mica.

The succession here detailed points out that the actual junction between the older and newer rocks is a wavy line with sharp and deep bends. In one place the granite runs into the slate in dykes and veins, while between these there are left jutting points and arms of the old rock standing between walls of granite. Junctions of a similar nature are described by Mr. A. W. Howitt in his able paper on the Diorites and Granites of Swift's Creek.*

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* Transactions of the Royal Society of Victoria, Vol. xvi. pp. 11-87.

Near Newbridge, the junction of the igneous and sedimentary rocks presents the same features. In a cutting on the Bathurst side of the railway station bars of igneous and slate rocks can be studied in actual contact. The boundary-line between the two is still sharp, and no evidence can be found of a slate merging into a granite. On the contrary, examples can be found where the intrusion of the granite in a liquid or pasty condition, but evidently under great pressure, has bent and crushed, and pushed on one side, the easily yielding slates. In cases where the granite does alter the rock with which it is in contact, the alteration consists in the development of a rock not in any way resembling a granite. Where the alteration is most complete, a hornfels is the result, and where incipient alteration is noticeable, a close examination reveals merely a rearrangement of old minerals and the introduction of only one new one. Between Locksley and Brewongle, on the railway line, a good example is exposed of the alteration produced by the intrusion of granite. Near a high level bridge, between these two stations, a mass of granite will be found lying partly to one side and partly under a micaceous and schistose rock. The granite sends veins into the overlying beds. This upper rock, as stated, is of a schistose character, and it will be noticed that the planes of schistosity are parallel to the mass of the intrusive rock. In this instance the schistose planes are horizontal, which gives the rock a bedded appearance. But in other parts of the district, notably on the Rockley Road, south of Peel, where a foliated or schistose structure is developed, the foliation planes are vertical. This inclines one to the view that an envelope of foliated rock once surrounded the granite mass, so that when a portion of the original sediments remain *above* the granite the schistose structure will be horizontal, but when they are seen forming a vertical boundary to the intruded granite the planes of schistosity will be vertical. In connection with this peculiar structural development, it may be mentioned that a schistose structure can be induced in wax and mixtures of oxide of iron and pipeclay by pressure,* and that, in these instances, the

* See Tyndall's "Fragments of Science," Vol. I. p. 366.

planes of the laminæ are found to arrange themselves in rudely parallel planes perpendicular to the lines of pressure. Whatever may be the explanation, we have here at Bathurst a foliated or schistose structure developed in sedimentary rocks when in contact with an intrusive granite. When a fragment of these ancient sediments is found above, and resting on, the granite, the foliated structure lies horizontally, and when found adjoining the granite mass, the folia stand vertically. A diagram showing the intrusive veins at Locksley will be found on Pl. xv. fig. 1. The sketches were made some eight years ago, when the face of the cutting was fresh. I examined the same section a few months ago, and although the rocks have disintegrated a little and vegetation is beginning to take hold there, the intrusive veins can be easily studied.

With the evidence of these sections before us, we are now in a position to enquire into the origin of the granite. Everything that we know points to the one conclusion, that the Bathurst granite is intrusive. The granite alters rocks with which it comes in contact. It sends tongues, veins and dykes into the adjoining rocks. Nowhere can we trace a gradual change from a sediment to a rock granitic in structure. The proximity of granite has converted phyllites into hornfels. It has caused a rearrangement of old minerals in the sedimentary strata, and caused the development of one new mineral in abundance, namely, mica. But this is all. Nothing approaching a granite can be found resulting from any metamorphic process, and in no one section have I ever discovered anything like a change from a clastic to a holo-crystalline rock, granitic in composition.

When I first examined the rocks around Bathurst the prevailing impression left on my mind was that the granite melted away by insensible gradations into the surrounding rocks. A more minute examination rendered this position untenable; but it will be interesting if we can yet discover a granite truly metamorphic in origin. There can be no difficulty, as far as chemical composition of some slates goes, in believing that the constituents of a slate rock may be rearranged so as to give rise to a rock that may not be distinguished from granite. The evidence advanced in support of the metamorphic origin of many granites broke down when the rocks were subjected to the test of microscopical examination. But there are still cases where all the refinements of modern geology have been employed without shaking the conclusion that some granites, at least, and certainly some crystalline schists, can be produced by the metamorphism of rocks *in situ*.*

There is little doubt, then, but that the granite was intruded into Silurian rocks after their folding and elevation. Possibly the granitic intrusion formed an anticlinal, and lifted the sediments yet higher. Silurian rocks once occupied the place now taken by the granite. Were the former rocks simply lifted or thrust aside, or were they absorbed by the molten or plastic granite? Lifted, I should say. There is little proof to show in support of this view, but it is an impression left after a study of the whole district. I have no doubt at all but that portions of the Silurian rocks were absorbed by the granite in its intrusion. When we examine the outer edges of the granite, we find that for a short distance from the contact it differs from the typical rock. There is, for instance, an absence of hornblende, the mica is in nests, and the minerals, generally, are not arranged as in a normal granite. Quartz, instead of filling up the spaces left by the other constituents, is found in grains and blebs through a much larger body of felspar. All this might be accounted for by the more rapid cooling of the margins of any intrusive rock. But I consider it as the result of the absorption of a certain amount of the pre-existing phyllites.

In this connection I would like to draw attention to some views on the origin of crystalline rocks as set forth in the volume of the International Geological Congress for 1888.†

In a paper on the "Archæan Geology of the Region N.W. of Lake Superior," Dr. A. C. Lawson points out that the archæan

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* See Green's "Physical Geography," Chapter IX., second edition.

† Congrès Géologique International 4me Session—Londres, 1888. Etudes sur les Schistes Cristallins.

rocks of that region can be resolved into two great divisions. The lower composed of rocks which but for their foliation are regarded as of plutonic igneous origin. Resting on these is a mass of stratiform rocks, partly detrital, partly volcanic. These latter, or upper series, were certainly not laid down on the lower. The old floor on which they were deposited has disappeared; and again, Dr. Lawson points out that the lower series could not have been the crust from which the detritus for forming the upper rocks was derived.

"There is but one way of reconciling these statements. It is a simple conception, and one well in accordance with established geological truth, that certain portions of the earth's crust upon which strata are accumulating may sink gradually. Now, that portion of it upon which the upper archean was accumulating, to a thickness of several miles, may be conceived to have been depressed, either by reason of the superincumbent weight or from other causes, till it came within a zone of a sort of fusion compatible with the conditions of such depths. This fusion gives us the magma which is implied in the conception of the laurentian gneisses, granites, and syenites, being of plutonic igneous origin."*

Vancouver Island furnishes another example that may throw some light on the origin of the Bathurst granite. Dr. G. M. Dawson has described the relations of granites to triassic beds in Vancouver and the adjacent coasts. Triassic beds are frequently found in contact with, or resting upon, granite rocks. They were not, however, deposited on a granitic floor, as the granites are evidently of a later date. "The circumstances attending the line of junction of the granites with the rocks of the Vancouver (triassic) series have been carefully examined at a great number of points. The granites near this line are usually charged with innumerable darker fragments of the Vancouver series, which, when in the immediate vicinity of the parent rock, are angular and clearly marked, but at a greater distance become rounded and blurred in outline, and might then be mistaken for concretionary

* Congrès Geologique International, Londres, 1889; pp. 75, 76.

masses in the granite, into the substance of which they have been in process of being absorbed. The width of the belt characterized by these fragments is very variable, and where the plane of the present surface cuts that of the junction of the two classes of rocks at an acute angle—as is often the case—it is considerable, frequently exceeding half a mile. . . . The only explanation which appears to satisfactorily account for the appearances met with, is, that we have at the surface a plane which was at one time so deeply buried in the earth's crust that the rocks beneath it had become subject to granitic fusion or alteration."*

The bearing of these extracts on the geology of Bathurst is obvious. Here we have Silurian rocks resting on a granite. There must have been a solid floor on which they were deposited. The granite on which they rest was certainly not the pre-existing basement. And it is extremely improbable that granitic rocks formed the crust from which the sediments were derived. Thus far the conditions are very similar; and it is hard to resist the conclusion that when the original floor of the Silurian was being absorbed in the granitic magma, some of the Silurian rocks suffered a like fate.

The Devonian and Carboniferous formations are now estimated, by Mr. C. S. Wilkinson,† to measure 20,000 feet in thickness. With two miles of strata resting on our Silurian rocks, we can see the possibility of the lowest series being brought within a zone of fusion, which would furnish the required magma, and make the Bathurst granite, in a sense, at once metamorphic and intrusive.

We have abundant proof, as shown above, that the granite is intrusive in character. It is quite another question to decide whether the material that forms the granite was drawn from a deep-seated source, or whether it is the result of the profound metamorphism of a previously existing sediment.

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* Annual Report of the Geological Survey of Canada, 1887; Report B., pp. 11-13.

† See "Notes on the Geology of New South Wales," by C. S. Wilkinson, F.G.S., contained in "Mineral Products of New South Wales;" Sydney, the Government Printer, 1887.

I am not in possession at the present time of sufficient material to deal with this question, but, as a first step towards a solution of the problem, I may state that there is abundant reason for believing that the granite exposed about Bathurst is but a small portion of a very large mass that underlies the palæozoic rocks on all sides. In keeping with this view, we find that the granite is exposed for a much greater distance up and down the river than across the valley. The lowest rock for miles around is probably granite, and the Bathurst rock shows merely where the overlying beds have been denuded.

Microscopic Examination of the Granite.—I have made some twenty-five slices of the granite for microscopic examination. Nearly all the minerals of the rock can be seen macroscopically, particularly in polished specimens. Certainly there are fine-grained varieties, but the average Bathurst granite is coarse-grained. Crystals of black hornblende are not unusual of 9 mm. in length. Glistening faces of felspars, 16 mm. long, are frequently found. In polished specimens the silica and felspars appear in about equal quantity, or perhaps with felspars slightly in excess. The minerals proved to be present by a microscopic examination are :—

Essential Minerals.	*Accessory Minerals.*
Quartz.	Muscovite.
Felspar.	Apatite.
Hornblende.	Sphene.
Biotite.	Garnet.
Magnetite.	Calcite.

Quartz.—Under the microscope, in plain parallel light, the quartz is easily distinguished from all other minerals by its water-clear appearance, the absence of inclusions, and its fresh, unaltered aspect. It is found filling up the spaces left by the other constituents. Under higher powers, inclusions will be noticed, but not in such quantity as to lessen the contrast between the clear quartz and the cloudy felspars. The hair-like lines that cut through the quartz in every direction fall under the heading of trichites, described by various observers. These trichites can be noticed striking in every direction through the clear quartz. A power of one hundred diameters shows them in great abundance. They branch, sometimes meet at a point, fifteen or twenty diverge from one point, and sometimes opaque blebs are found at various points along their length, or, more often, at the end. I can offer no explanation as to their real nature. Cavities are abundant in the quartz. They can be detected in every slice. I have noticed one spontaneously moving bubble. Besides the trichites and bubbles, tubes can be seen in the silica with a power of fifty diameters. They are evidently tracks left in the plastic mass by moving bubbles of gas.

Examined in polarized light, with crossed Nicols, the quartz displays the usual gorgeous broad sheets and bands of colour, one colour imperceptibly shading into another. In very thin slices it appears a dull blue-grey. The great abundance of cavities in the silica of all the slices is explained by the fact that the quartz was the last mineral to crystallize. When rocks that have cooled from an igneous magma are studied, it is often noted, as we should expect, that the most fusible mineral was the last to crystallize. But it is found that this does not apply to granitic rocks. Every student knows that quartz is commonly called infusible, while the felspars are considered fusible in various degrees. In the consolidation of granite from an igneous fluid or paste, felspar was the first to crystallize, while the more infusible quartz filled up the interspaces and was the last to solidify. Our granite is no exception to the rule, for the silica occurs in an amorphous state, enclosing the other minerals as in all true granites. This is explained by supposing that the original plasticity was induced in some other way than by what we understand as dry igneous fusion. The fluid inclusions prove the presence of water and various salts. The quartz, being the last to harden, took in any fluid residue and, from its enduring nature, retained it. A notable feature of the quartzes, under the microscope, is the presence of microscopic dust which seems to have accumulated on the outside surfaces of the quartz granules.

The proportion in which the minerals occur, as revealed by the microscope, may be expressed as follows, felspar being the commonest :—1. Orthoclase ; 2. Silica ; 3. Triclinic felspars ; 4. Biotite ; 5. Hornblende ; 6. Magnetite ; 7. White mica.

Felspars.—With crossed Nicols, the felspars can be readily divided into orthoclase and into felspars with distinct triclinic striations. The orthoclase occurs in sub-crystalline patches, and, in most slides, is the more plentiful of the two. In its general appearance the orthoclase is always cloudy, even in the thinnest sections. The cloudiness and opacity of the orthoclase is a constant character in all the slices I have cut. I attribute this peculiar dimness to pores and fractures that no doubt hasten incipient kaolinization. This structure has, no doubt, a great deal to do with the "sickening of the rock" before referred to. Indeed, anyone accustomed to micro-petrographical work, would, on account of these characters, at once decide that the rock was not of an enduring character.

Triclinic Felspars.—The banded appearance, so characteristic of the triclinic felspars, is at once noticeable under crossed Nicols in every slice. The amount of plagioclase relative to the orthoclase varies much. The plagioclase is often in excess, and sometimes the two felspars seem equal in quantity. I sent a few slices of this rock to Mr. A. W. Howitt, our leading Australian petrologist, and he decided, from the structure of the crystals and from their obscuration angles, that the felspar was oligoclase. Sections are not uncommon with the fine bands of colour crossing at an angle of 90°. This felspar contains inclusions of other minerals that had crystallized before itself. Magnetite is a common inclusion, as well as corroded crystals and plates of hornblende.

Hornblende.—Every slice will show hornblende more or less plentifully under the microscope. The crystals are generally much corroded, showing that they were formed long before the felspars. A few examples show the exact prismatic hornblende. Most of the sections, however, are in zones other than the prismatic, and show only one set of cleavage lines. In thin sections it appears of a deep brown colour, and sometimes of a rich sap green. Nearly every slice has a favourable section on which the angle, formed by an axis of elasticity and a crystallographic axis, can be measured. Sometimes it is not easy to distinguish between hornblende and biotite in slices of the Bathurst granite. For the information of students who may make use of these notes, I may just indicate the difference. The micas, including of course biotite, show no sensible dichroism in sections parallel to the base. In sections across the cleavage the biotites will show very strong dichroism on rotating the lower Nicol prism. Hornblende is also dichroic, but a few sections can usually be found on the slice parallel, or nearly parallel, to the base; these will show two sets of cleavage. Sections of hornblende, parallel to the vertical axis, show but one set of cleavage lines, and in this resemble mica. But the cleavage planes of the hornblende are generally coarse, or seldom so close as those in mica. Mica, too, has usually a more ragged look than hornblende, and the ends of the laminæ have a frayed-out appearance. Finally, unless the section be cut exactly parallel to the orthopinacoid, hornblende does not extinguish when the cleavage lines are parallel to a diagonal of the Nicols. Between crossed Nicol prisms all sections of biotite will be black when the cleavage corresponds with the plane of vibration of either Nicol, since the cleavage corresponds with an axis of elasticity. With hornblende this is not the case, and, in the larger number of its sections, the point of maximum darkness will be obtained when the cleavage makes a certain, though not great, angle with the plane of the light.

Biotite.—Biotite is common in all the slices. It appears as irregular plates, with parallel striæ, corresponding to the cleavage on sections, parallel to the vertical axis. The absorption exhibited by rotating the polarizing prism under the section is very marked. Sometimes flakes show of a light brown colour, without any cleavage lines, exhibiting no dichroism. These I take to be biotites cut parallel to the basal planes or cleavage. They resemble, in every respect, flakes or plates cleaved from biotites and mounted separately for comparison.

Muscovite.—Muscovite is, comparatively speaking, rare. Mr. A. W. Howitt first pointed out its presence to me. It is common enough in the aplite and kindred rocks on the borders of the granite country. But in the main body of the granite it has been, up to the present, detected only under the microscope.

Magnetite is readily recognised in every slice by its remaining opaque in the thinnest sections, and by its peculiar lustre in reflected light. Sphene is another rare constituent. It appears in clear brownish-red granules. Sometimes wedge-shaped crystals can be seen with dark or almost opaque edges.

I have selected four fairly typical slides from my rock slices, and I will give a short description of their microscopic characters.

1. (Slice 48). The general appearance of this slice under the miscroscope is that of a holo-crystalline rock. Some of the micas and hornblende show crystalline faces, but the quartz and felspars are, for the most part, allotriomorphic. With crossed Nicols, a considerable quantity of plagioclase becomes visible, but it is altogether subordinate in amount to the orthoclase. The quartz occurs in broad plates, filling up the interspaces between the other minerals, and showing in polarized light the customary brilliant colours. Glass cavities and fluid cavities are very abundant in the quartz. Fluid cavities, with bubbles of gas, can be readily found with a magnifying power of about seventy-five diameters. By using $\frac{1}{8}$ immersion lens, cavities containing spontaneously moving bubbles can be detected. The Bathurst granite affords abundant material for studying this wonderful phenomenon. The slide I am describing contains many good examples of spontaneously moving bubbles. Some of these bubbles move round the cavities slowly, reminding one of the movements of a rotifer in search of food. Others are stationary until the slice is slightly heated, when the bubbles are seized with a sort of trembling motion and suddenly start off travelling round the cavity. I have noticed many in which the movements are so rapid that it is difficult for the eye to follow them in their course. In this slice brown dichroic mica is abundant. It becomes almost dark in some positions as the

polarizer is rotated. There are also a few crystals of hornblende, which is also strongly dichroic; but, as has been already explained in a former portion of this paper, there is little danger of confounding the two minerals. The orthoclase felspar is cloudy, appearing of a snowy white by reflected light. The hornblendes contain some bright green patches of decomposition matter.

2. (Slice 38). This slide contains a hornblende crystal 4·6 mm. along its vertical axis. The largest patch of quartz is 2 mm. by 1·8 mm. Triclinic felspars are present showing a beautiful banded structure under crossed Nicols. The quartz is clear and limpid, containing few inclusions other than the fluid cavities. The hornblende and biotite are the only minerals showing traces of boundary planes.

3. (Slice 34). The minerals present are quartz, biotite, felspar, orthoclase, and triclinic felspar. Fluid cavities are very plentiful in the quartz, numbers coming into the focus of the glass as the different planes are reached by the fine adjustment. The felspars are in places almost impellucid. A few crystals of magnetite are included in a flake of biotite.

4. (Slice 37). Under the microscope some finely striated, clear brown mica is seen. Even in the thinnest section it is strongly dichroic. When the cleavage lines are parallel to the plane of vibration of the light, the sections are black or very dark brown. A few crystals of apatite are enclosed in the quartz and biotite. A reddish-brown wedge-shaped sphene will be noticed on the margin of the slice. The biotite alters to a leek-green material that often preserves the dichroic character, but the cleavage lines are lost. The felspars as is usual are impure and cloudy, and the quartz beautifully pellucid. The hair-like microlites, to which reference has been already made, are abundant. Triclinic felspar is present, but not so plentiful as orthoclase.

Chemical composition of the Granite.

Specific gravity at 18·5° C..........2·85-2·93

I am indebted to Mr. Mingaye, F.C.S., of the Geological Survey Laboratory, for the following analysis of the granite. The specimen submitted for analysis was fairly typical of the general character of the rock :—

Hornblende-biotite-granite.

Silica	66·69
Alumina	17·03
Ferric oxide	3·15
Ferrous ditto	·69
Manganous ditto	trace
Lime (Ca O)	1·82
Magnesia (Mg O).	2·50
Potash (K_2 O)	6·26
Soda (Na_2 O)	1·21
Phosphoric acid	trace
Sulphuric anhydride	trace
Titanic acid	trace
Moisture	·48
	99·83

Comparing the above with well-known granites, it will be seen that the Bathurst rock contains about 10 per cent. less silica than the normal type of West of England granite, while it is richer than the average granite in alumina and potash.

Basalt.

The basalts have been defined as dark-coloured lavas of basic composition and high specific gravity, representing the extrusive or volcanic type of the gabbros and dolerites. Dr. Geikie limits the term basalt to the contemporaneous lavas of basic composition.* They consist of a compact or finely granular ground-mass, through which crystals of plagioclase, augite and olivine are scattered. Again, some authors use the terms dolerite, anamesite and basalt† for rocks which, chemically identical and all holo-crystalline, differ

* British Petrography, by J. J. Harris Teall, M.A. ; London, 1888, p. 193.

† Professor J. G. Bonney—Anniversary Address to the Geological Society, London ; Quarterly Journal Geological Society, Vol. XLI. p. 70.

in the coarseness and fineness of their grains, so that the last term is applied to a rock which either may be holo-crystalline or may retain a glassy base. It would be convenient, then, to restrict the term dolerite to the holo-crystalline variety, using the epithet coarse-grained or fine-grained as the case may be; to apply the name anamesite to the hemi-crystalline varieties; and to include in the term basalt all that retain a glassy base.

The Bathurst rock I shall refer to under the name of basalt simply. It is not as fine-grained as the typical anamesite, nor as coarse-grained as a dolerite, and the amount of glass in the base is variable. I would describe the Bathurst basalt as a blue-black, compact, apparently homogeneous rock, that breaks with a splintery and conchoidal fracture, and in which the component minerals can be studied only with the microscope, unless occasionally scattered porphyritically through the mass. It occurs as a contemporaneous flow and consists essentially of triclinic felspar, augite, olivine and magnetite, with small portions of an unindividualised glassy base.* Zirkel, in studying the basalts of the fortieth parallel of North America, separated the felspar-bearing basaltic rocks into four distinct groups.† The Bathurst rocks would naturally fall into the group which he describes as "possessing a microscopically very fine-grained, totally crystalline aggregation of crippled microlites, largely felspar and augite, which serve as a ground-mass, in which micro-porphyritical and macro-porphyritical larger crystals of felspar and olivine, with occasional augites are distinctly and sharply embedded." Add magnetite and occasional patches of a glassy base, and the above description answers fairly well for the Bathurst rock. Of course, in speaking of basalts generally, we would call our rock a felspar

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* The fact of its being a contemporaneous flow does not affect the classification. I agree with the English geologists who refuse to accept the geological age of a rock as a character on which its nomenclature ought to be based. See Judd, "On the Tertiary Gabbros," &c., of Scotland, Q.J.G.S., Vol. XLII. p. 60.

† Zirkel, Microscopical Petrography of the Fortieth Parallel; United States Geological Exploration, p. 253.

basalt, which would distinguish it at once from the leucite basalts that are known to occur at Harden, Byrock, and Cobar. Compared with the basalts immediately around, those of Orange and Carcoar for instance, the Bathurst rock is distinctive enough. This is most easily detected in preparing thin slices for the microscope. Long before the slice is sufficiently thin, the Orange basalt is seen, by transmitted light, to consist of a felted mass of plagioclase, with augites and olivines for the most part wedged between. The Bathurst slice on the contrary will show micro-porphyritic minerals in a holo-crystalline base with an abundance of magnetite and drop-like grains of augite. Basalts of this type are not uncommon in Europe and America. The resemblance extends even to such minute details as the serpentinization of the olivines, and the sharp well-marked features of the iron oxides. Zirkel's remark, relative to the American basalt, applies well to this Australian example. "It is worth while," he says, "to pause and remark that in these widely remote quarters of the globe the product of the solidification of a molten mass, although exposed to many casualties, has nevertheless maintained a surprisingly close identity of microscopical composition."*

Basalt in the Field.—A glance at the map accompanying this paper will show the extent of the basalt. It marks the course of an old river valley. At the outside it is not more than 150 to 200 feet in thickness where it lies deepest. It can be studied well at the quarries on the Bald Hills, where stone is obtained for road purposes. Perth railway station is very convenient to the hill marked F. Here the basalt forms one of those table-topped hills which, in the western district, are invariably recognised, even from a distance, as basaltic. The road from Perth to Evans' Plains crosses a saddle in the hills. On this road sections of decomposed granite are exposed, where the weathering of the rock can be noted. About half way up the hill water-worn pebbles will be found, increasing as we ascend. These have weathered out from the drift that lies between the granite and basalt. As soon as no

* Zirkel, l.c. p. 233.

more water-worn pebbles can be found, it may be taken for granted that the highest point of the drift and the lowest point of the basalt have been reached. The weathered surfaces of the rock on the hill tops show no evidence of the prismatic structure underneath. This prismatic structure may be seen in the quarries referred to. They are situated on the line A—B. The columns are utilised in their natural state for kerb stones. They break in some directions with a conchoidal fracture, while in other directions the stone can be broken in parallel flakes. From Perth the basalt may be followed without a break to the point marked L. Here there is an isolated hill with a basaltic cap, known as the Pinnacle. The table-topped hill overlooking Evans' Plains is the next remnant of the once continuous sheet. Then there is a long break to Mt. Pleasant, near Mr. Stewart's residence. Perth and Mt. Pleasant are the extreme points of the basaltic flow around Bathurst. Of course these points were not the original limits of the basalt plateaux. Allusion has been already made to the source of this basalt. Mr. Wilkinson pointed out that the stream came down from the neighbourhood of Swatchfield. Possibly a microscopic examination of the Swatchfield basalts could throw light on this question. It is certain, however, that no volcanic "neck" or traces of a crater exist within a radius of ten miles of Bathurst.

Very little has been done to expose the drifts under the basalt, so that some idea may be gathered as to the nature of the old valley. Along some points, where the basalt has been entirely worn away, there is an abundance of silicified wood strewn about the surface. This, no doubt, has been derived from the drift, and shows that the river valley flowed through a forest-clad region. At the present time the ridge of basalt forming the Bald Hills stands from 400 to 600 feet above the surrounding country. In the pre-volcanic days it was of course the lowest point. We have here, then, a splendid example of the effects of subaërial denudation. The old mountains and valley have both disappeared, and the untiring hand of Nature has spread out the material of which they were composed over the great tertiary plains of the interior. In this connection I must draw attention to a fact oftentimes overlooked when dealing with our geology. We are, for the most part, accustomed to consider the material removed by denudation as eventually carried to the sea. None of the material removed by denudation from around Bathurst in Tertiary times ever reached any sea. It was disposed of in the same way as is the vast amount of material brought down each year by the Macquarie. None of this material ever gets to the sea, but is deposited over the plains between Dubbo and the Darling. "The precipitous and rugged country about the Upper Macquarie, the chains of basalt capped hills in the Bathurst district, and all the surfaces which form the valley of the river down to Wellington, have been carved into their present shapes by the subaërial influences of air, frost, rain, and rivers. Near Dubbo we might draw the line which would show the limit of deposition, denudation and deposition being synchronous and co-equal. The basaltic hills referred to have their representatives at Dubbo, but with their summits barely on a level with the surrounding country."* Professor A. Geikie describes geological features very similar to our own in a paper on the "Tertiary Volcanic Rocks of the British Islands." Referring to the ridge of Eigg, he says :—"In Eigg a fragment of the river valley has been preserved solely because it has been sealed up under streams of vitreous lava which could better withstand the progress of waste. Thus the Scùr of Eigg, like the fragments of the older basalt-plateaux of Auvergne, remains as a monument not only of volcanic eruptions, but of a former land surface, now effaced, and of the irresistible march of those slow and seemingly feeble agencies by which the denudation of a country is effected."

It is very probable that a columnar structure is developed along the line of hills, but unfortunately there are no natural exposures of this interesting phenomenon. A large opening has been made nearly on the line of section A B, Pl. xvi. Here the columns of basalt show well. Many are curved in a peculiar manner, but for the most part the columns are straight. Between the joints they vary in length from two to seven feet. The cup and socket

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* J. Milne Curran, "Notes on Geology of Dubbo." P. L. Soc. N.S.W. Vol. X. p. 170.

structure so characteristic of the jointings in basalt is nowhere to be seen. The joints are planes, sometimes normal to the sides of the columns and sometimes forming small angles with them. As regards thickness, there is no uniformity in the columns. The average size might be taken as eighteen inches across. The weathering of these columns is rather noticeable. As the basalt decomposes it peels off in layers, and the centres of these films are fairly fresh. Plate XVII. shows this peculiar weathering.

The columns are, for the most part, tetragons, pentagons, and hexagons. With regard to the relative frequency of the various kinds, the following may be taken as a fair estimate—tetragons 4 per cent., pentagons 20 per cent., hexagons 65 per cent.

I made some measurements of the angles of the basaltic columns with these results:—

Tetragons (sum = 360°):

(i.) a	93°	(ii.) a	113°
b	110	b	81
c	88	c	83
d	68	d	82
	359°		359°

Pentagons (sum = 540°):

(i.) a	112°	(ii.) a	133°
b	121	b	118
c	81	c	100
d	115	d	98°
e	95	e	89
	524°		538°

(iii.) a	114°
b	130
c	80
d	105
e	96
	525°

Hexagons (sum = 720°):

(i.)		(ii.)	
a	117°	a	113°
b	132	b	133
c	118	c	111
d	120	d	111
e	123	e	123
f	107	f	124
	717°		715°

In hand specimens, the Bathurst basalt bears a strong resemblance to the Rowley Regis basalt of Staffordshire. It is not unlike, in its texture, a basalt in my own collection from Madeira. It differs, however, from the basalt flows of the same age about Orange and Dubbo. It is commonly known as "blue metal," and I think that the Bathurst rocks have a decidedly bluer shade than the generality of western basalts. This peculiar blue-black is noticeable only on fractured surfaces, polished surfaces being very dark or almost black.

Microscopic Structure of the Basalt.—I have cut thirty slices of this basalt, collected at various points between Perth and Mt. Pleasant. Five slices were cut from rocks from the high hill overlooking Perth. Ten slices were made from the columnar basalt in the quarries already referred to, and were taken from an average depth of fifteen feet from the surface. A few slices were collected from the hill known as the Pinnacle, and the remaining number from Mt. Pleasant. Under the microscope there is no essential difference between any of the slides. In fact there is not even a structural difference between the slices from the most widely separated localities.

In grinding down the sections, the first mineral to show is olivine. While the section is still comparatively thick, the microporphyritic crystals of olivine are seen as clear spots in the, as yet, opaque slice. The next mineral recognisable is invariably the augite, and as the section thins down the plexus or network of the tiny felspars becomes visible. As the section grows thinner, the base resolves itself into tiny globules of olivine, augite and felspar. In this ground-mass augite is much more abundant than would be supposed at first sight. In every slice black grains of magnetite are plentiful, and remain opaque in the thinnest sections. It is usually well preserved and shows no signs of decomposition. It was the first mineral to separate from the glassy magma, and is the only primary constituent ever enclosed in the olivines. Broadly speaking, the structure is decidedly micro-porphyritic.

A "streaming of the felspars" is a very characteristic structure at once recognised under the microscope. It is hardly pronounced enough, however, to be termed a fluxion structure. The lath-shaped plagioclases are often seen sweeping round the larger olivines and augites, pointing, without doubt, to movements in the molten magma. This structure is shown on Pl. XIV. figs. 4 and 5.

The abundance of black magnetite which remains opaque even in the thinnest slices is the next feature to attract attention. From Professor Judd's researches, I could conclude from this feature alone that the rock cooled at or near the surface. As Professor Judd remarks,* in most deeply-seated rocks the iron oxides enter into complete combination with the silicates, and in other cases there is a progressive increase in the quantity of magnetite which is separated according to the proximity to the surface at which consolidation has taken place.

Magnetite was one of the first minerals to separate from the magma. It is the only mineral ever included in the olivine, but its enclosure in this mineral is a very common occurrence. The large olivine crystal on Pl. XIV. fig. 4, shows a cube of magnetite. The felspars, too, it will be noticed, seem for the most part perfectly fresh and unaltered. These plagioclases exhibit parallel twin-striation in polarized light, a feature common to rocks of this sort throughout the globe.

The olivines are abundant in every slice, showing, as is usual, that peculiar ground glass surface which helps to identify it.

* Q.J.G.S., Vol. XLII., p. 88.

Olivine is of course no longer regarded an essential constituent of basalt, but it occurs in such remarkably fine crystals in these rocks that their presence distinguish it at once from all Australian basalts with which I am acquainted. By taking a micro-photograph and cutting out the portions representing the olivines, the percentage of olivine can be calculated. With the porphyritic crystals this is easily done, but in estimating the granular olivines of the base a large margin for error must be allowed. The application of this method is common with petrologists, and was originally devised by Dr. Sorby.* I have cut several micro-photographs in this way with fairly even results for the average structure of the rock.

Porphyritic olivine ...	...	...	13 per cent.
,, augite	...	...	9 per cent.

This comparatively large percentage of olivine would bring the rock under Rosenbusch's class of olivine-basalt.†

Besides the large crystals of olivine there is the granular olivine which with augite and felspar form the base. Under a magnifying power of 100 diameters a micro-photograph can be got of this granular base, from which the parts representing olivine can be cut. My experiences gave me 23 to 29 as the percentage of this mineral in the base.

A glance at the micro-photographs appended will show the presence of porphyritic augites. But there is also a very large amount of augites in the micro-granular ground-mass. The quantity of augite is easily shown by treating the slice (after first getting a micro-photograph) with warm hydrochloric acid. After four hours' digestion, the magnetite, serpentinous matters and olivine dissolve, and the felspars and augite only remain; olivine and magnetite being soluble in HCl., while the augite and plagioclase are scarcely affected.

* J. J. H. Teall, "Petrological Notes on some North of England Dykes." Q.J.G.S., Vol. XL., p. 216.

† H. Rosenbusch, Micro-Physiographie der Massigen Gesteine, Zweite Auflage, p. 733.

Another reaction that renders the olivine of the ground-mass distinct enough from the augite is effected by treating the slice with warm HCl., until on gently drying the olivines gelatinize slightly, when they can be stained by fuchsin. The olivines will then stand out in marked contrast to the augites.

In many of the slides patches of an isotropic glass can easily be detected, particularly with the help of the quartz plate. The glass often seems of a light wine-red colour by transmitted light. I notice that prolonged treatment with acid has no appreciable effect on this substance. The glass is, therefore, not of a tachylytic nature, but more acid in character.

From what has already been said it will be gathered that there are two generations of olivine, augite and felspars in the Bathurst basalts. This is quite in keeping with the observations that have been made on similar rocks in the Old World. In the peridotites it is common to find olivine in the ground-mass and the same mineral as porphyritic crystals. In many dolerites labradorite and augite form the principal ingredients of a ground-mass in which the same minerals occur porphyritically.* I have met with no explanation altogether satisfactory of this common condition of igneous rocks. In the paper just referred to Dr. Bonney remarks that although an explanation of these anomalies does not seem hopeful, we may bear in mind that the temperature of consolidation for a mineral out of a magma is not necessarily identical with that of the isolated mineral, as one substance acts as a flux on another.

As throwing some light upon this interesting question of the separation of minerals from a molten magma, the following extract from a paper by Professor Judd applies to our own rocks.

"In some instances the mechanically injured condition of the crystals and other appearances strongly suggest their actual transport from below in the midst of the materials of the surrounding ground-mass. But in others the porphyritic crystals exhibit zoned structures and other characters not found, perhaps, in the deeper-

* See Professor T. G. Bonney, Q.J.G.S., Vol. XLI., p. 79.

seated rocks of the class in the same area. May we not in these cases explain the phenomena in the way suggested by M. Michel-Lévy by the consolidation having taken place at two different periods? It is not difficult to imagine conditions which would bring about such a result. If, for example, a mass of igneous materials were in a liquid state at a great depth from the surface, the conditions might be favourable to the separation of a felspar of a given composition from the magma. The continued abstraction of certain elements from the base would alter the composition of the surrounding magma, and this would modify slightly the conditions causing the successively formed zones of the crystal to vary slightly in composition. But if a fissure were formed above such a molten mass, then the pressure upon it would be greatly and suddenly relieved, even though no actual movement occurred in the deeper-seated portion. Under the entirely new conditions thus originated, the magma surrounding the zoned crystals already formed might be induced to crystallise in a totally different manner, the order of the separation of the minerals and the forms and relations of their several crystals being determined by these new conditions."

As some of the minerals in the basalt present features worth noticing, I may refer to the characters they present when seen under the microscope.

Olivine.—The porphyritic crystals of olivine are so abundant that, with very few slides, sections may be found in various zones sufficient to study its leading optical properties. I have noticed sections close to basal planes, and sections approximately parallel to the macropinacoid, so as to show an interference figure in convergent polarized light. Sections roughly showing the form of an elongated hexagon are plentiful. The peculiar ground glass surfaces, due to its high refractive index, are very pronounced. In fairly thin slices the mineral shows a very faint yellow-brown colour. But the most remarkable feature in the olivine is the fact that it is the first mineral in the rock to fall a victim to alteration. Every large crystal shows serpentinous lines of decomposition. I have not met with an instance where the alteration is complete. The green serpentinous matter follows the cracks and cleavage lines and gradually eats its way across the intervening spaces. The micro-photographs on Pl. XIV. figs. 2 and 4 show this change clearly enough.

The edges of the olivines are sharply defined and show little or no signs of corrosion. The form of the crystals does not seem affected in any way by the surrounding minerals, so that, to use a term of Rosenbusch's, they are for the most part idiomorphic. Inclusions of magnetite are common, as well as patches of a semi-devitrified glassy base. It is more than probable that some of the large olivines were formed at a depth and floated up before the second generation of olivines consolidated. On Pl. XIV. fig. 1 will be noticed a crystal of olivine that was broken along a central line; one half is seen in the micro-photograph, and the other half is found on another part of the slide.

Augite.—The augite in the Bathurst basalt is not penetrated by the felspars, so as to give rise to an ophitic structure. But the consolidation of the augites must have been subsequent to that of the felspars. The augite is sometimes to be seen partly moulded around the ends of the laths of plagioclase. An example is shown on Pl. XIV. fig. 5. Here a large zoned augite is seen partially penetrated by a felspar as if the latter was forcibly carried against the augite when the pyroxene was still in a plastic condition.

On slide 41 an augite will be found with well defined edges. It shows a figure in convergent polarized light. Faint traces of cleavage lines seemingly parallel to the prism can be detected, so that it is evidently a basal section. The same slide shows some good examples of zoned and twinned augites. On slide 46 a fine example can be found of a porphyritic augite sliced in the clinopinacoidal plane. The crystal is partially penetrated by a felspar, and with inclined Nicols shows the well known hour-glass structure often noticed in augites.

Felspar.—Mr. A. W. Howitt made some measurements of the felspars in this basalt, and noted that, as all the obscuration angles measure 20° in the zone $OP \infty \bar{P} \infty$, the felspars were not more basic than andesine. For the present it will be sufficient to describe the felspar, whether andesine or labradorite, as plagioclase. Twin crystals are very common in every slice. Sometimes broad cruciform twins are seen, one good example of which may be noted on slide 41.

Magnetite.—I have never isolated the black crystalline bodies which I have provisionally named magnetite. On being analysed they may prove to be ilmenite or titaniferous magnetite. By drawing a magnet through detrital matter, near the basalt, large quantities of a magnetic iron can be collected. This gives a strong reaction for titanium. I have not been able to decide whether this may not be derived from the adjoining granite.

The magnetite in the basalt I take to be a primary constituent. It is invariably sound and undecomposed. It can be noticed enclosed in clear augites and olivines. I have noticed secondary magnetite in other basalts, but in that case the olivine and some of the augite had disappeared, and the iron of the ferro-magnesian minerals was represented by the magnetite. The augites in our rock are beautifully clear, and no olivines are wholly decomposed.

I have selected three slices as fairly representing the microscopic character of the whole basalt. I will describe their general structure.

1. (Slide 45). The micro-porphyritic structure of this slide is just visible to the unaided eye. Under the microscope large olivine crystals are seen, set in a paste or granular base of magnetite, augite and felspar microlites. The olivine crystals are beautifully clear, magnetite and blebs of glass being the only inclusions. The olivines are better preserved than it most slices, showing very little signs of serpentinization. The streaming of the felspars is very characteristic. One large olivine has evidently moved when the paste was partially set, as it is seen to have pushed on either side a collection of felspars. Besides the lath-shaped felspars, broad rectangular plagioclases of another species probably are represented. The magnetite crystals seem disposed to gather around the edges of the augites and olivines.

2. (Slide 48). Large twins of augite can be detected without the use of the microscope, their yellowish-brown colour contrasting with the other almost colourless minerals of the slice. Under the microscope the greater number of the lath-shaped felspars show incomplete terminations. A few small olivines are seen altered completely to a light green serpentine. Many other patches of a like green secondary product, that show no definite boundaries, originated in the same way. All the magnetite seems a primary constituent. A few large augites show lines of uncertain inclusions just inside their boundaries and parallel to the outer edges of the crystal. With inclined Nicols, faint traces of zones can be detected. There is very little glassy matter.

3. (Slide 9). Under the microscope, shows the general structure of the Bathurst basalt. Porphyritic crystals of augite, olivine and plagioclase, set in a much finer ground mass of the same minerals, with cubes of magnetite abundantly developed. The felspars flow round the augites, but are not seen to penetrate them, so there is no arrangement approaching to the ophitic structure. Patches of a light red isotropic body are seen set in the dark hemi-crystalline base. It is probably glass. The large compound augite has some inclusions of the same material. The augite contains well marked cubes of magnetite as inclusions. The olivines are seen cracked in directions evidently independent of the cleavage lines. They are also somewhat corroded along their outer edges.

The microscopic structure of the basalt is so uniform along its length in the field that the above descriptions may be taken as fairly typical of the whole.

Chemical composition of the Basalt.

Specific gravity at 18·5° C..........2·63-2·75

Silica	44·67
Alumina	21·38
Ferric oxide..................................	2·82
Ferrous ditto.................................	5·99
Lime (Ca O)................................	10·24

Magnesia (Mg O)	9·58
Potash (K_2 O)	1·03
Soda (Na_2 O)	2·70
Phosphoric anhydride	·22
Sulphuric ditto	trace
Titanic acid	trace
Moisture	·79
	99·42

For this analysis I am indebted to Mr. J. Mingaye, F.C.S., Analyst to the Department of Mines. The chemical composition shows a basic rock quite in keeping with its microscopical characters.

To facilitate the future study of the rocks of Bathurst, I now append a few remarks to point out the means of seeing the various features of interest in connection with the district. The passage from a granitic to a slate country, and the characters that accompany the change, can be observed in a morning's drive. By taking the Peel Road, *via* Kelso, tertiary drifts are seen on the right from Kelso to the trigonometrical station, at the first turn to the right. Granite country continues until the descent is begun to the valley of the Winburndale Creek. In this creek, and in a small tributary already referred to, contact rocks can be noted. When the village of Peel is reached the student finds himself in the midst of slate country. Take the road that leads back to Bathurst, *via* Duramana. Some worked out alluvial deposits can be examined on the creek. With a local guide then follow the road to Rankin's Bridge, *via* Kelly's farm and Duramana. About Kelly's farm hornfels rocks, semi-granites, and the weathering of granitic boulders can be studied. Getting on to the main road to Rankin's Bridge we are again in granite country ; outcrops of the rock are plentiful near the bridge. From the road near Seage's farms good views can be had of the sheets of the basalt away to the south, forming the Bald Hills at one extremity and Mount Pleasant at the other.

On reaching Peel another route could have been taken. Beyond the village a road leads away to the right through Silurian slate country. This road joins the Bathurst Limekilns road, which latter can be followed home. At the bridge crossing the Winburndale, good casts of Brachiopods—*Spirifer* and *Rhynchonella*—can be found in the water-worn pebbles of the creek. These have been washed down from the Devonian sandstones that are extensively developed up the valley.

A very good idea of the slate and schist country about Cow Flat can be gained by driving south through Perth, and following the Rockley Road to the top of the first range. Here contorted slate, clay slate and crystalline limestone crop out. A road through Cow Flat to George's Plains railway station leads away to the right. Along this latter road splendid examples of metamorphosed rocks, slate country and quartz reefs can be seen.

Basalt is best seen by ascending the Bald Hills at Perth, and then following a track that leads along the hill tops to Bathurst, *via* the basalt quarries and Poor Man's Hollow. A separate trip should be taken to study the drifts and basalt on the hill over Evans' Plains, and the same rocks at Mount Pleasant.

The localities of the contact rocks have been already referred to in sufficient detail.

X. Economic Geology.

Gold.—There is little prospect of finding payable gold in quantity immediately round Bathurst. It is not probable that it has been derived from the granite. We therefore fall back on the only alternative that it has been drifted from a distance. And the nearest auriferous country whence it could have been derived is too far away to leave any hope of heavy deposits.

Granite.—For building purposes the granite will hardly ever become a marketable commodity. Even at a depth the felspars are kaolinized and the whole rock suffers from incipient decomposition. True it will take a polish, but I have had an opportunity recently of examining a polished slab of Bathurst granite that had been exposed to the weather for eleven years. Already the laminæ of biotite were fraying out, and the large hornblendes were honey-combed and had quite lost every trace of polish. Disintegrated granite is used extensively about Bathurst for walks and gardens in the same way as gravel is used in other countries.

Basalt.—The basalt is used extensively for road making, for which it is admirably suited. It is fortunate that there is so large a reserve of this useful rock in the vicinity of the town. It is sometimes used for building purposes. The basalt can be easily dressed with a hammer into rectangular blocks, and buildings in which it is used must be of an enduring nature. Its very dark colour is its only fault. It is as durable as any building stone need be. Some that has been in use for fifteen years shows no trace of weathering, being so dense and compact that not even a lichen had taken hold on its surface.

Kaolin.—The deposits of kaolin have been frequently tested and condemned, chiefly on account of a rather high percentage of iron that they contain. When good fire-clay and kaolins are so easily procurable in the colony, it is hardly likely that the Bathurst article will prove of economic value.

Copper.—The lodes of copper about Cow Flat were at one time extensively worked. Many who are familiar with the under-ground workings are of opinion that they will yet prove a source of wealth. The whole country about Cow Flat is highly favourable for mineral deposits. A belt of highly mineralized country runs from here along the granite boundaries. Large deposits of pyrites occur in highly metamorphosed slates. Very little has been done to test their value.

To the north of Bathurst the country about Peel seems favour-able for auriferous reefs. Odd samples of copper-stained rocks are occasionally found in the metamorphic rocks round Duramina. These point to the occurrence of copper lodes not yet discovered.

Clays.—Excellent clays for brick-making are found all along the alluvial flats. Where the alluvial material mingles with the decomposed basalts the bricks improve both in quality and colour.

XI. Other Points of Interest.

About eighteen miles to the north of Bathurst some very interesting geological country is easily accessible, particularly about the Limekilns and the Ben Glen caves, where good collections of Silurian fossils can be made.

At Blayney a finely typical example of the interesting rock diabase occurs. It will be found in a small quarry near the R.C. Church. To the naked eye it might pass for a diorite, but on slicing the rock it is seen to consist entirely of felspar, magnetite, and a monoclinic pyroxene, augite. The augites are porphyritic, and many of them beautifully zoned.

At King's Plains, near Blayney, rich and extensive patches of gold bearing drift are known to occur, which have not been worked chiefly on account of the great body of water that has to be contended with. Gold also occurs here in a steatitic slate, which once contained large quantities of pyrites. The pyrites has altogether disappeared, but the rock is full of cubical cavities pointing to its former existence.

I have in my own collection a monster twin pseudomorph of pyrites found here, in which the faces of the cube measure two and a half inches.

About Carcoar some highly interesting gabbros are extensively developed. These are holo-crystalline rocks of coarse texture, consisting of pyroxene and felspar. In calling these rocks gabbro I follow Professor Judd's classification in his paper on the gabbros of Scotland and Ireland.*

At the Three Brothers Hills, between Bathurst and Blayney, an interesting basalt is found with a flaggy structure. I have not examined the locality, but I have seen slabs of basalt brought in from there varying in thickness from two inches to four.

Steatite is found in a slaty condition about Rockley and Locksley.

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* Q.J.G.S., Vol. XLII., p. 61.

Wood opal, that polishes well, can be collected in some paddocks between the cemetery and Mount Pleasant. Good fire opals are known from Rocky Bridge Creek, where they occur in a decomposed trachytic lava flow. Good coloured amethysts and rose quartz are frequently brought in from the country between O'Connell and Oberon.

XII. Conclusion.

1. Getting results together we find that about Bathurst granitic rocks are extensively represented.

2. This granite area is surrounded by an aureole of metamorphic rocks.

3. There is no insensible gradation from a clastic to a holocrystalline rock, from a sedimentary rock to a granite.

4. The granite is intrusive as regards the surrounding slate rocks.

5. This is not necessarily opposed to the view that part of the granite may have been formed by a whole or partial fusion of pre-existing sediments. Like the granites of Vancouver, the Bathurst granite is probably at once intrusive and, in a sense, metamorphic.

6. The silurian slates are the oldest rocks now represented in the district—older than the underlying granites.

7. The granite comes next in order of time.

8. The granite rocks underlying the slates are not the floor on which the slate rocks were originally laid down.

9. This floor has entirely disappeared through sinking within a zone of fusion, or through being absorbed by an ascending molten magma.

10. Under the microscope the granite is a hornblende-biotite-granite with a triclinic felspar.

11. On a microscopic examination the "blue metal" is found to be a true olivine basalt and an old lava flow that filled up an ancient river bed. The point of eruption was near Swatchfield.

No doubt pages and chapters of the geological record are missing, but the foregoing is my reading of the history of Bathurst as written in her rocks.

EXPLANATION OF PLATES.

PLATE XIV.—Reproduced from microphotographs of thin slices of Bathurst basalts. Fig. 1, ×50, shows the general structure of the basalt at Pinnacle Hill. To the right two olivines are seen, traversed by serpentinous lines of decomposition. The lower olivine represents one half of a crystal, the other half of which floated away to a considerable distance. The lath-shaped felspars show a tendency to stream round the large crystals. Fig 2 is a basalt from Mt. Pleasant, enlarged 50 diameters. A very characteristic olivine occupies the right of the figure. The dark lines following the cracks are bright green decomposition products. On the other side of the figure there is a large plagioclase, containing some inclusions of the base. Fig 3 shows a thin slice of basalt from the quarries at Bald Hills, enlarged 50 diameters. At the top of this figure there is a portion of a micro-porphyritic olivine, and some distance below a basal section of augite. These and other large crystals are set in a micro-crystalline ground mass. The lath-shaped felspars show a decided flow. The magnetite is very abundant as black grains. Fig. 4, ×90 diameters Under this magnifying power magnetite shows clearly. The large olivine in the upper portion of the figure shows inclusions of this mineral, one being a perfect cube. The other large crystal is an idiomorphic augite. Between these two crystals a streaming of the felspars is very noticeable. It will be remarked that the felspars have incomplete terminations and sometimes bifurcate at either extremity. Fig. 5.—In the lower left hand portion of this figure a large augite is seen partially penetrated by two plagioclase prisms. The smaller lath-shaped felspars flow round the augite in an interesting manner. Magnetite is scattered through the slide. The two clear spaces at the top are olivines. The thin slices in Figs. 4 and 5 were cut from basalt used for kerb-stones in Bathurst, and quarried on the Bald Hills a few miles south of the city.

PLATE XV.—Fig. 1 shows a vein of granite intruding a much altered sedimentary rock. Between Brewongle and Lockslev this section is exposed in a railway cutting. Fig. 2 shows an intrusive vein in Silurian slates, on the outer boundary of the granite, near Newbridge. Fig. 3 is a sketch of forking veins of binary granite, near Newbridge. Fig. 4 shows a younger and lighter-coloured granite penetrating a dark coloured rock of the same character. Figs. 5 and 6 show veins of granite cutting through altered sedimentary rocks. These were sketched in the Winburndale Creek, above the bridge on the Bathurst-Peel Road. Fig. 7 represents junctions between slates and granite. The line of junction is very sharp and well defined, and is exposed in a railway cutting on the Bathurst side of Newbridge railway station.

Plate xvi.—The highest point of the basalt is about 600 feet above the river. The drift which is shown under the basalt was pierced by a tunnel. The relations of the rocks to the sections are drawn from notes made during the progress of the tunnelling works. Fig. 2 gives the relative positions of all the basalt around Bathurst. Some four miles of the ridges do not show in the sketch, as at the left of the section the chain of hills bends away south at right angles and so is hidden from view. The view is from the north.

Plate xvii.—Prismatic basalt, Bald Hills. This quarry is very nearly on the line of section marked A B on the map. The weathering of the rock is shown. Large flakes of decomposed matter peel off the sides of the prisms. These flakes are from half an inch to one and a half inches in thickness, and often contain a core of undecomposed basalt. As work goes on it is probable that better columns will be exposed.

Plate xviii.—Sketch map representing the boundaries of the basalt as accurately as is possible on this scale. It is easy to join the isolated patches and thus trace the former course of the river.